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(54) **METHOD OF CONTROLLING THE PITCH VELOCITY OF A WIND TURBINE BLADE AND CONTROL SYSTEM THEREFORE**

(75) Inventors: **Ole Mølgaard Jeppesen**, Risskov (DK); **John Bengtson**, Højbjerg (DK); **Torben Møller Hansen**, Hornslet (DK)

(73) Assignee: **Vestas Wind Systems A/S** (DK)

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**F03D 7/02** (2006.01)

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(58) **Field of Classification Search** ..... **416/1, 416/30, 37, 41; 290/44, 55**

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,418,446	A *	5/1995	Hallidy	322/28
5,584,655	A	12/1996	Deering	
6,137,187	A *	10/2000	Mikhail et al.	290/55
6,670,721	B2 *	12/2003	Lof et al.	290/44
2004/0094964	A1	5/2004	Mikhail et al.	

FOREIGN PATENT DOCUMENTS

DE	31 06 624	9/1982
EP	0 942 168	9/1999

OTHER PUBLICATIONS

International Search Report; PCT/DK2004/000512; Apr. 14, 2005.

\* cited by examiner

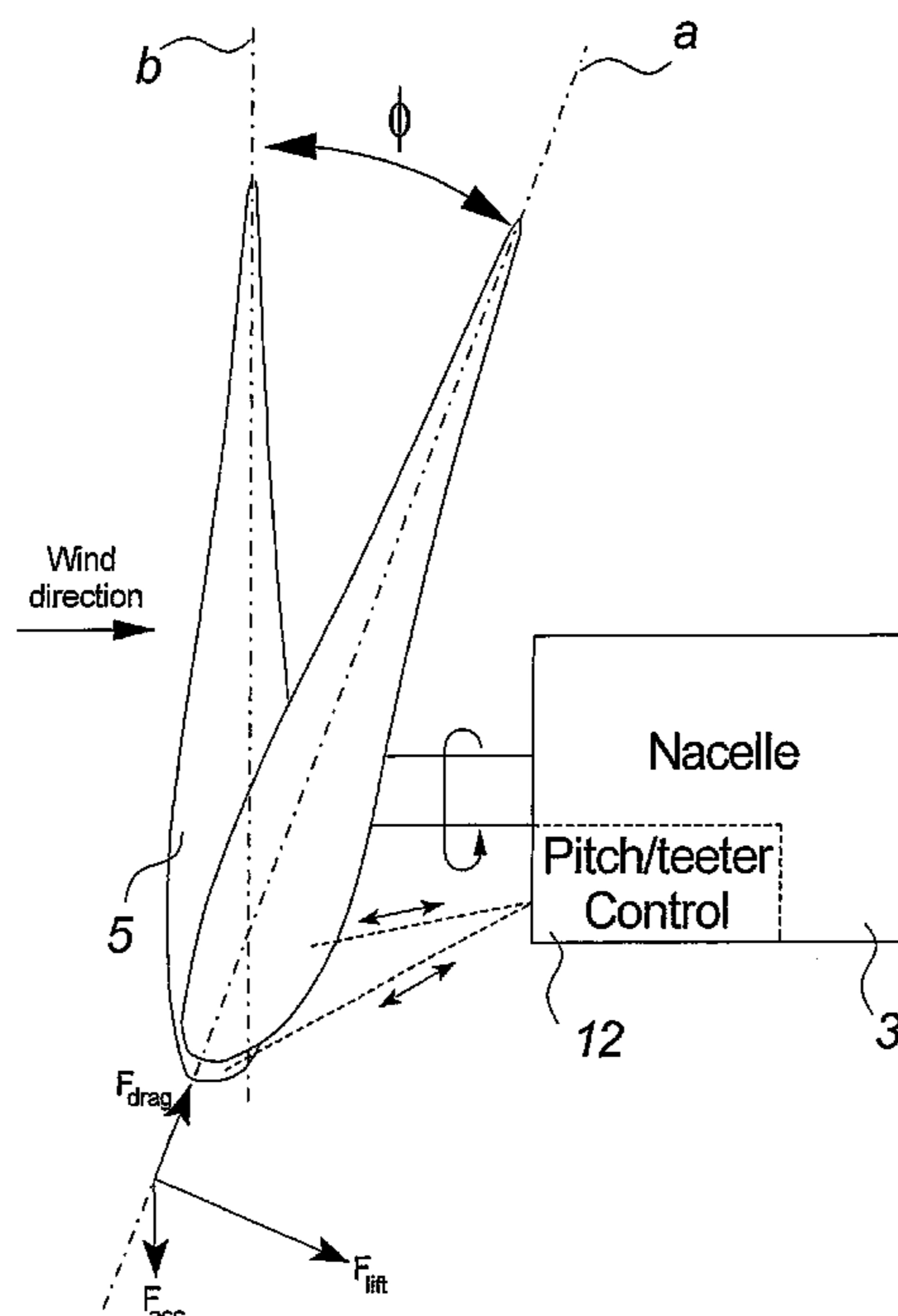
*Primary Examiner*—Igor Kershteyn

(74) *Attorney, Agent, or Firm*—St. Onge Steward Johnston & Reens LLC

(57) **ABSTRACT**

A method of controlling at least one wind turbine blade during the stopping process of the rotor in a wind turbine system is disclosed. The method optimizes the control velocity of the process in response to one or more feedback values of the system and/or one or more feedback values from the surroundings of the system by altering the angular pitch velocity from 10°/sec during the initial stage of the stopping process to 5°/sec at the final stage of the stopping process. A control system and a wind turbine as well as use hereof are also disclosed.

**26 Claims, 8 Drawing Sheets**



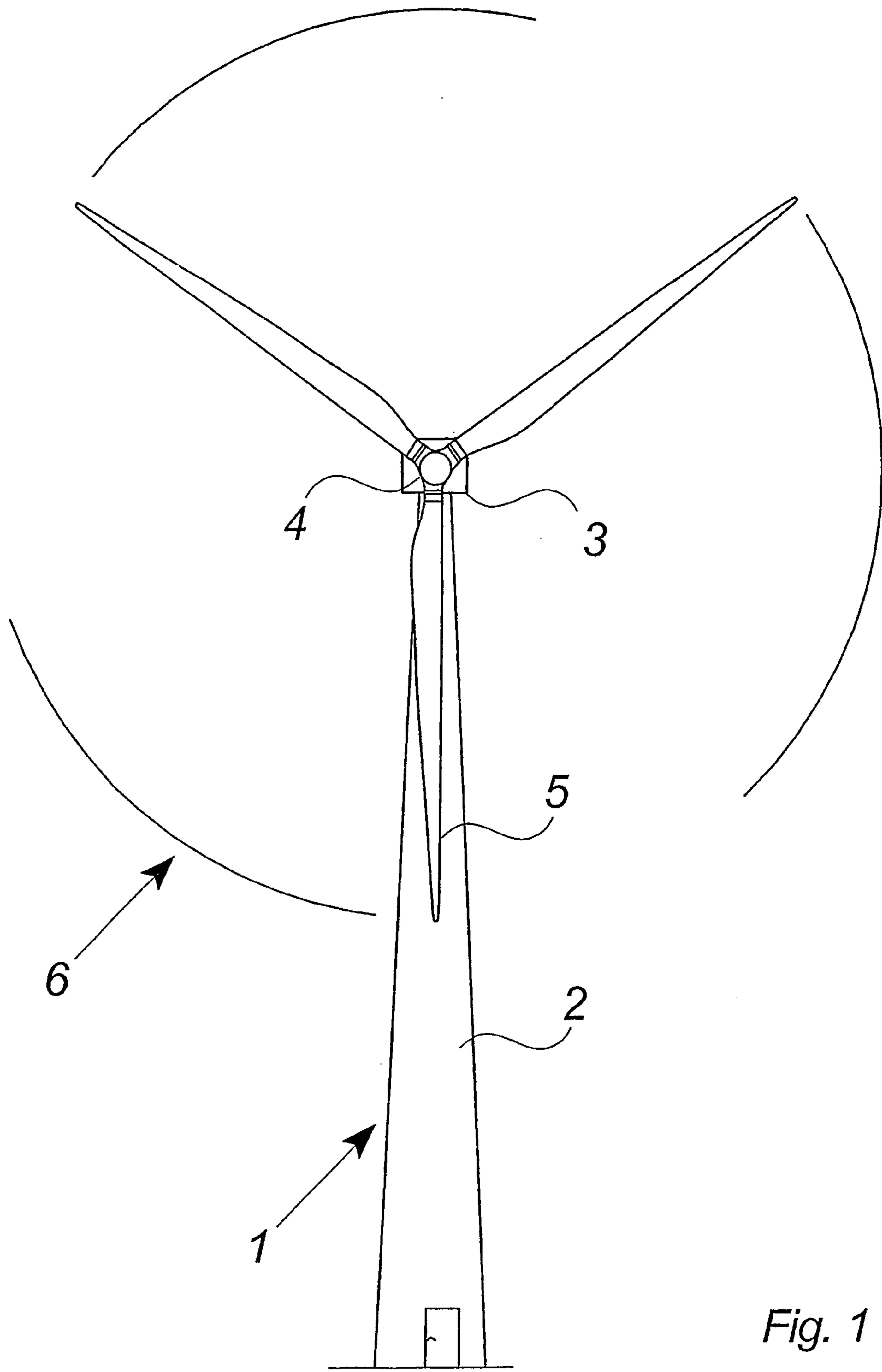
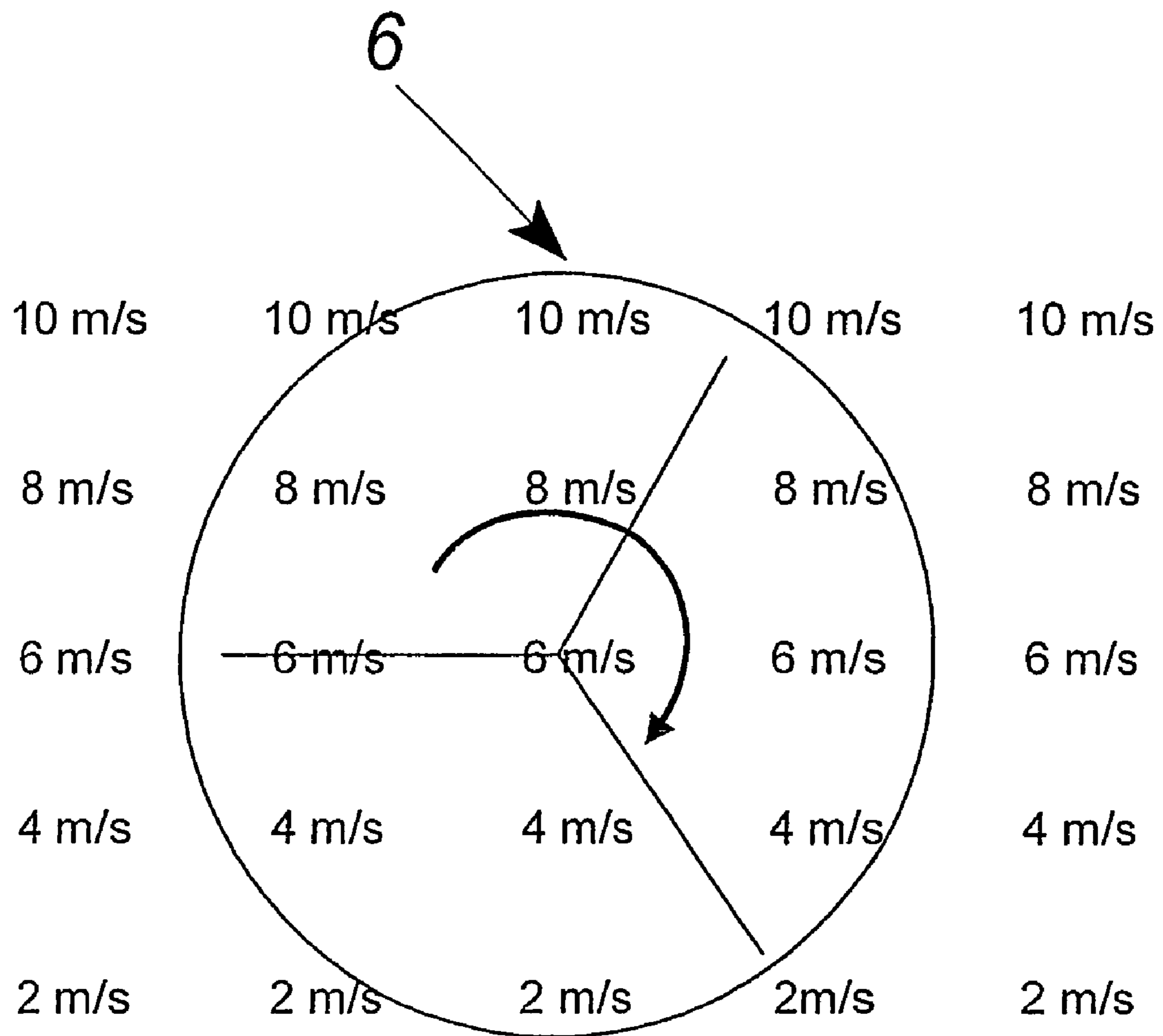


Fig. 1



*Fig. 2*

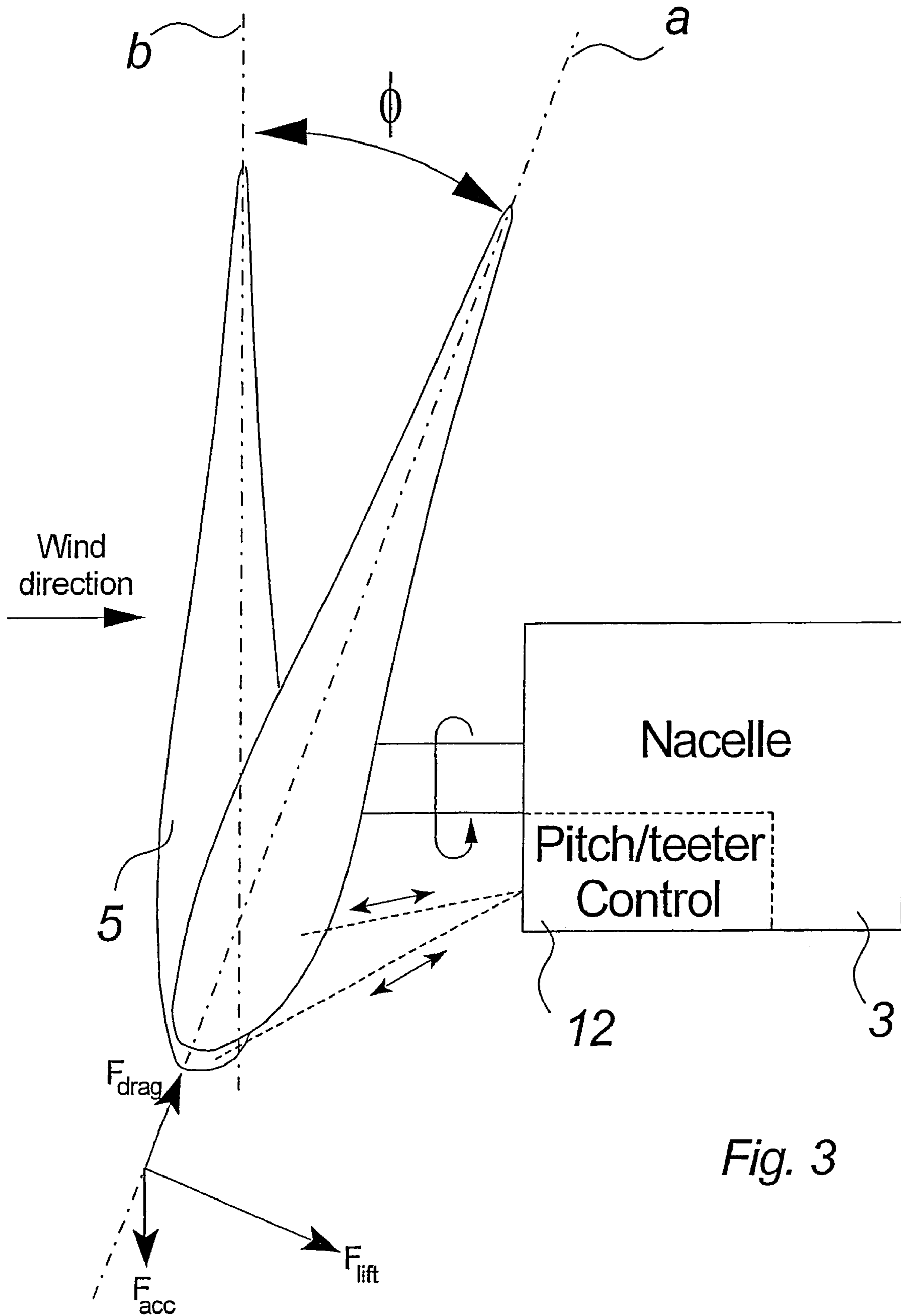


Fig. 3

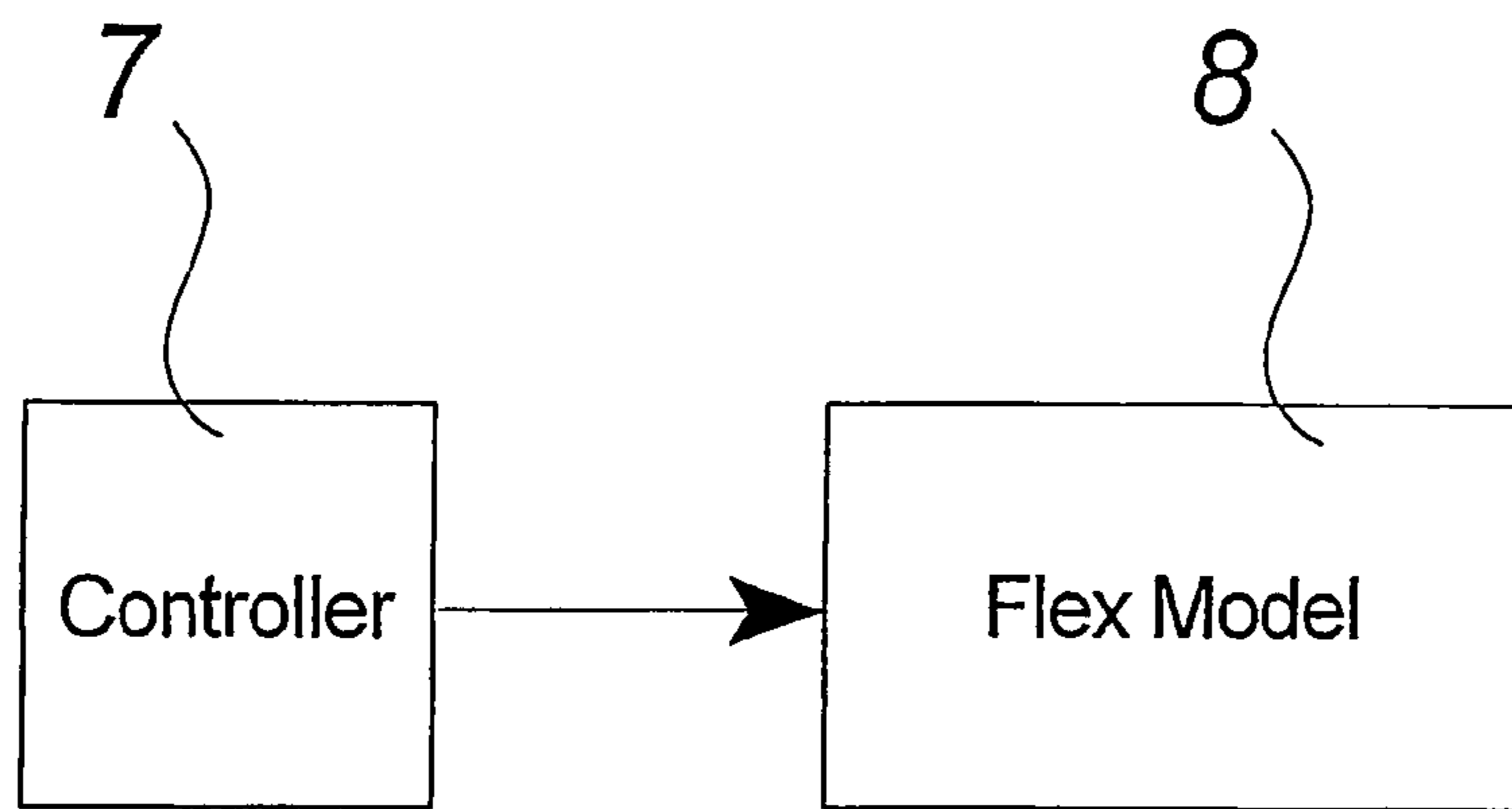


Fig. 4

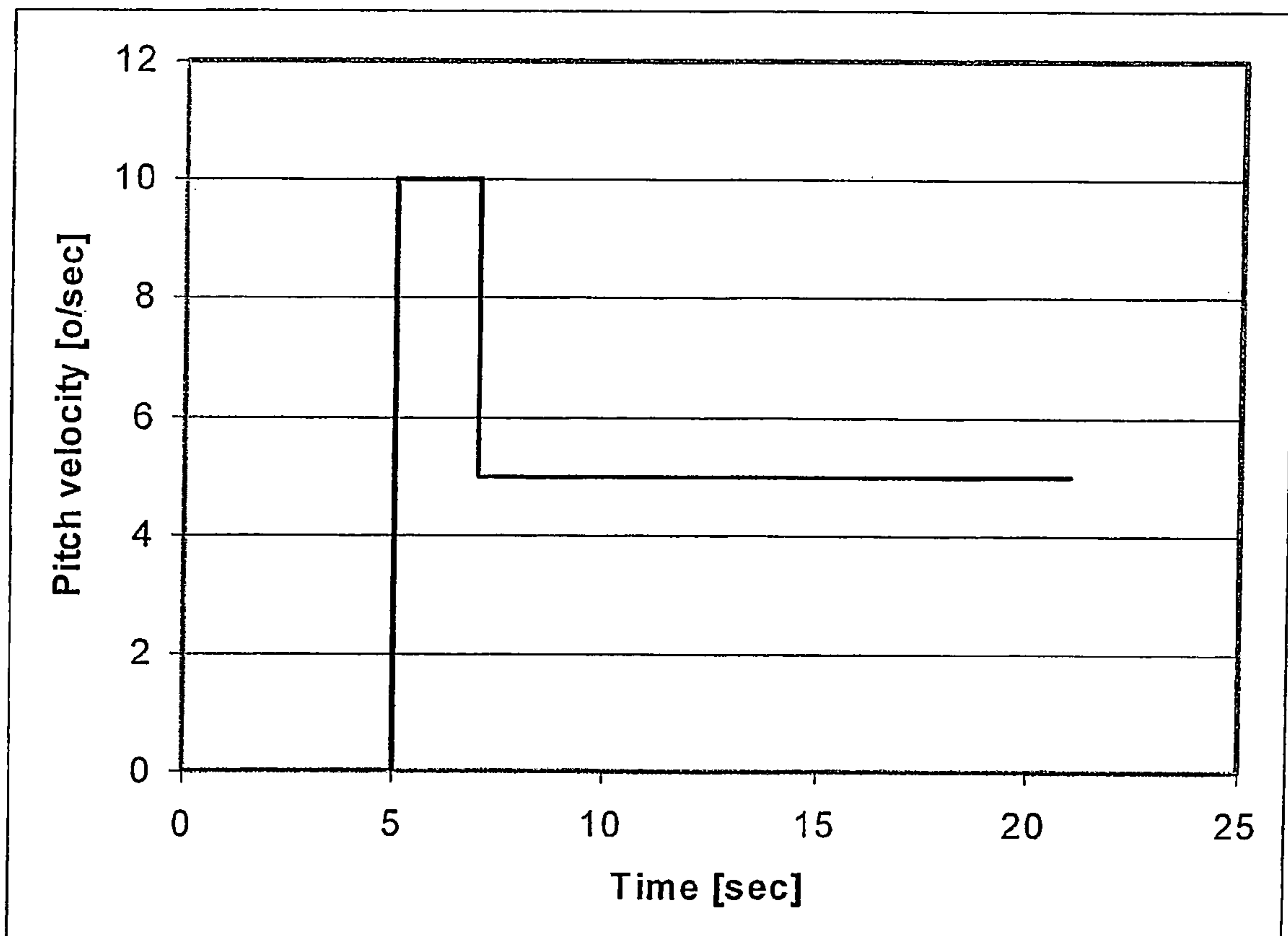


Fig. 5



Cyclic pitch at emergency stop

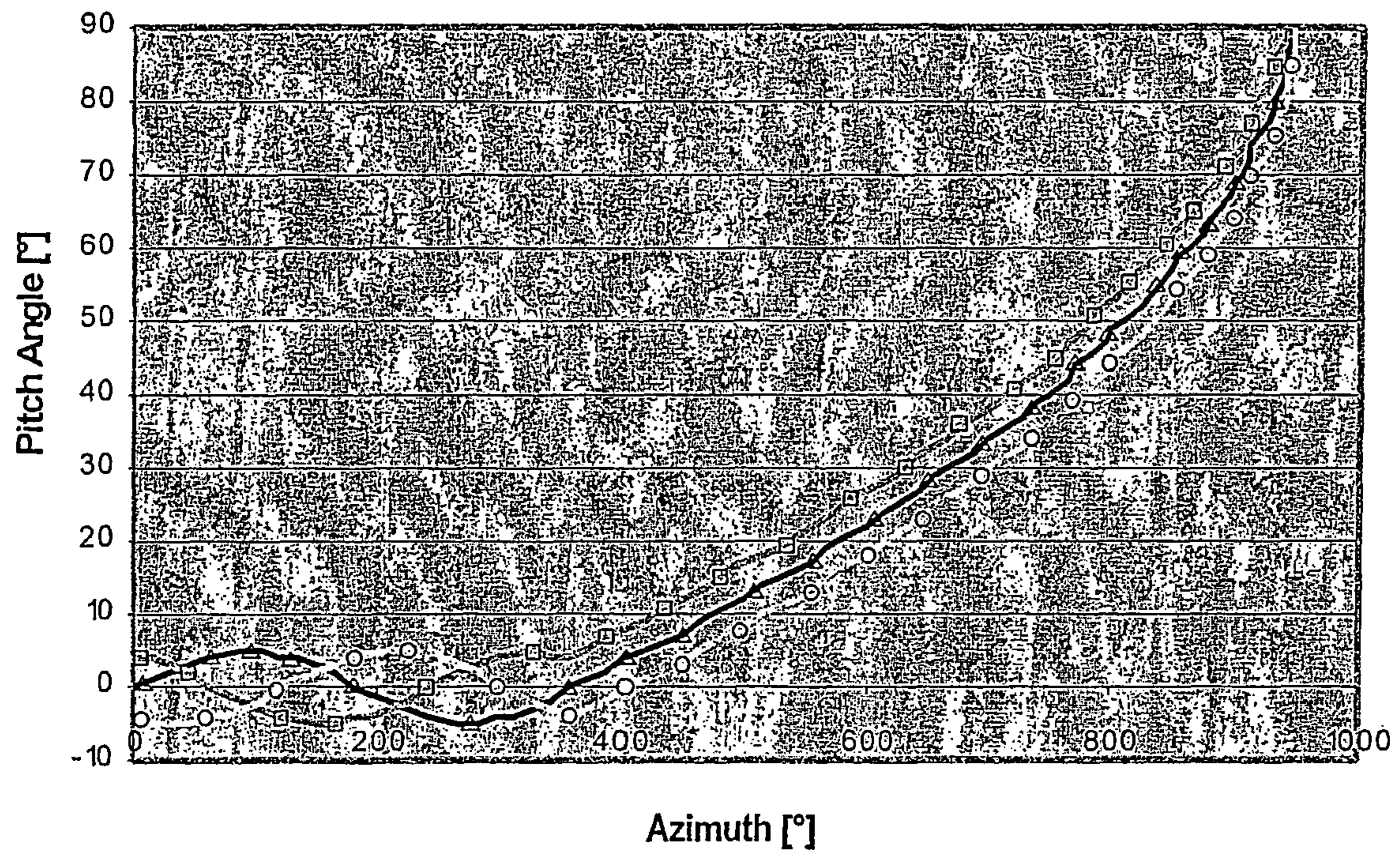


Fig. 6

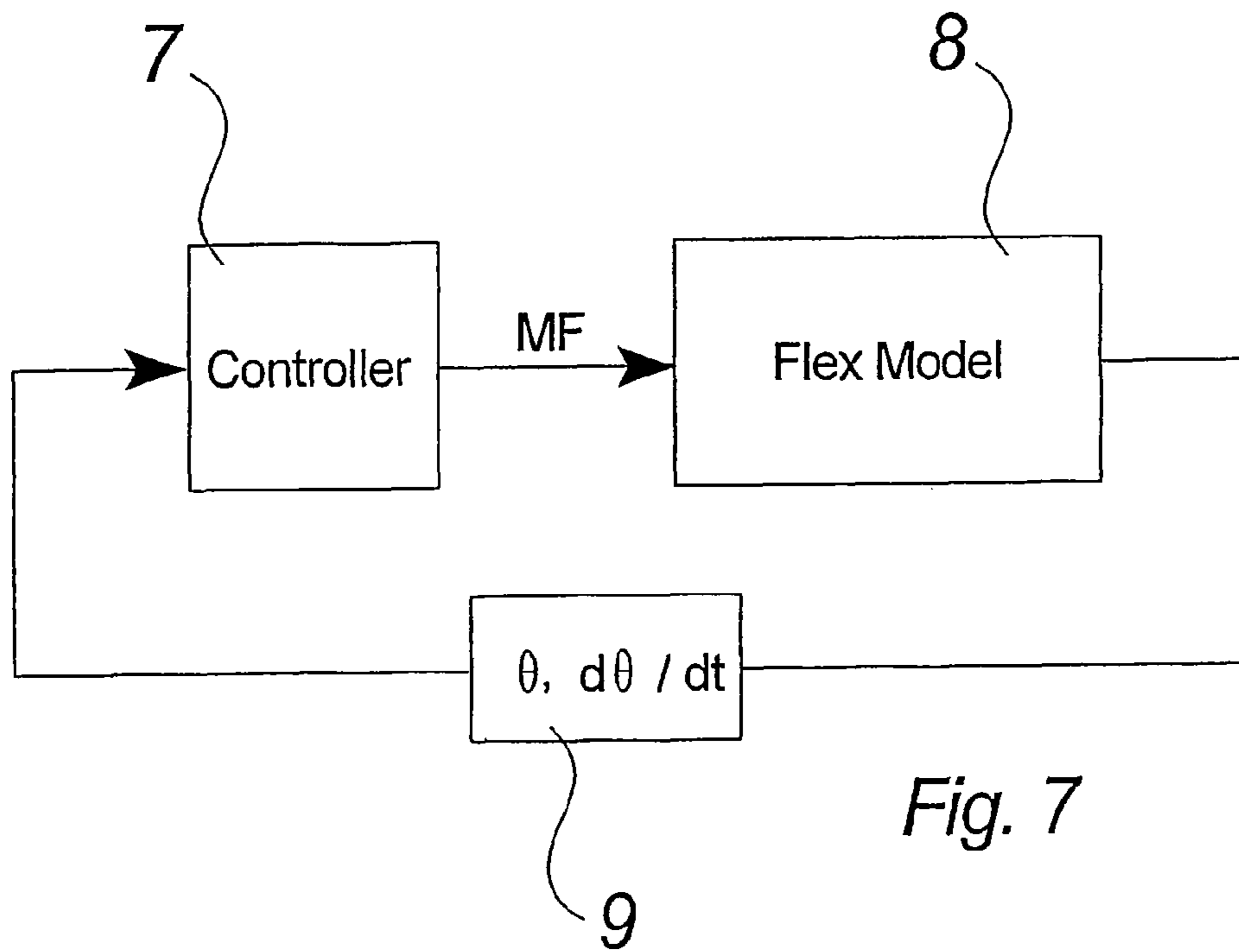


Fig. 7

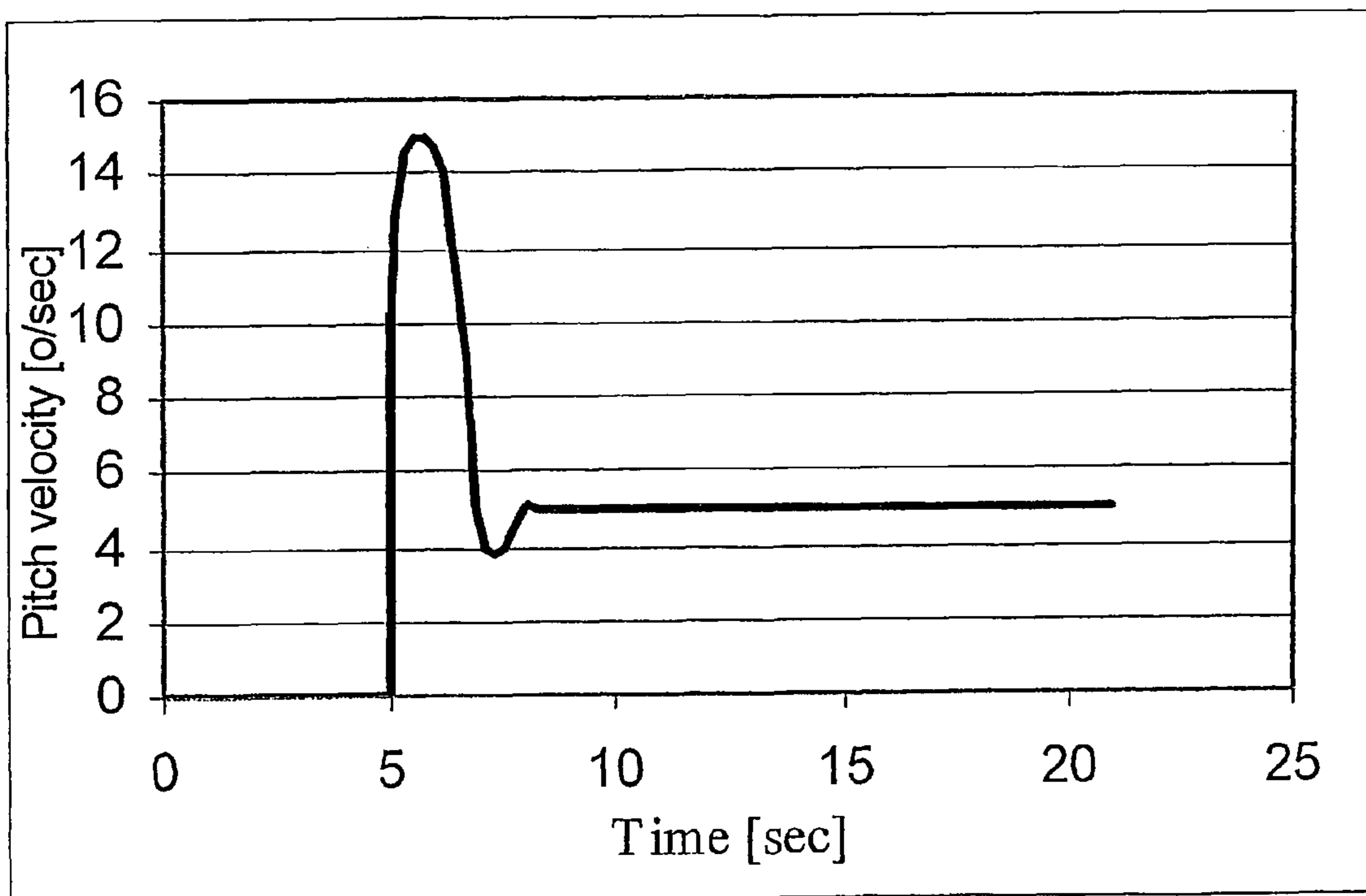
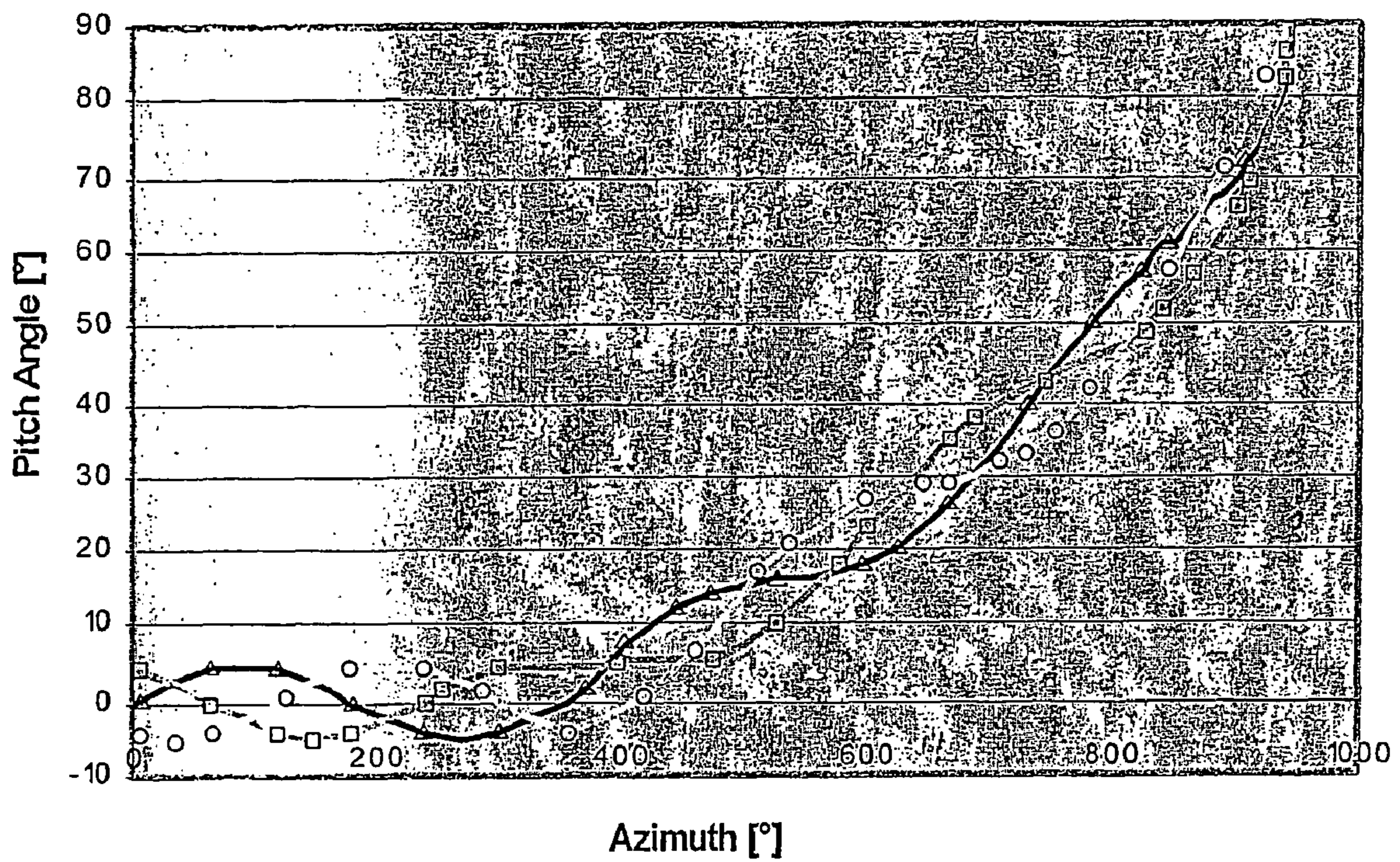


Fig. 8



Cyclic pitch at emergency stop



*Fig. 9*



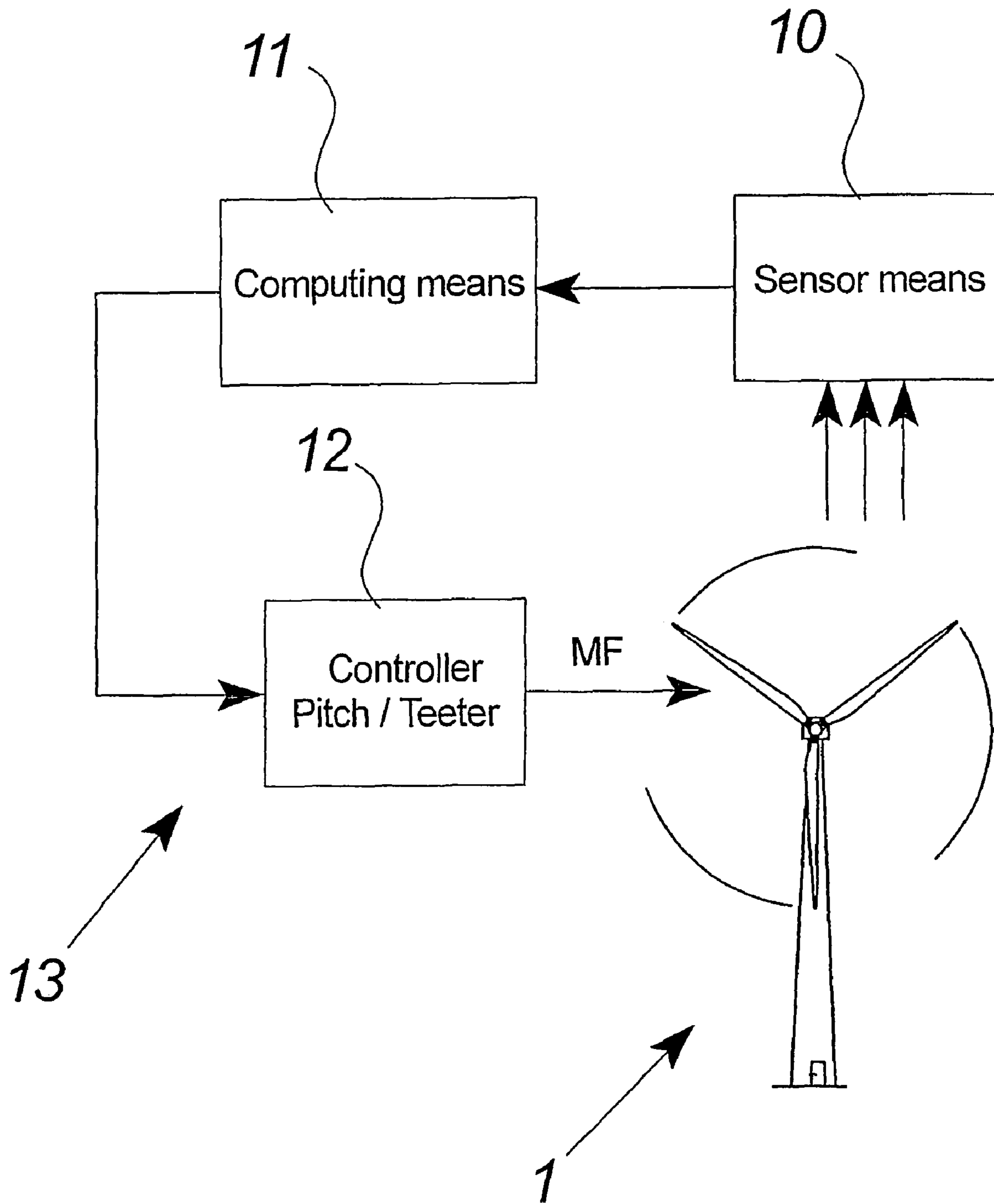


Fig. 10

## METHOD OF CONTROLLING THE PITCH VELOCITY OF A WIND TURBINE BLADE AND CONTROL SYSTEM THEREFORE

### TECHNICAL FIELD OF THE INVENTION

The invention relates to method of controlling at least one wind turbine blade during stopping process of the rotor in a wind turbine system, control system, wind turbine and use hereof.

### DESCRIPTION OF THE RELATED ART

The stopping process may be initiated in order to avoid overload situations for a wind turbine e.g. if the electric generator of the wind turbine suddenly is disconnected the utility grid.

Previously, wind turbine blades of a wind turbine have been controlled during a stopping process by using pre-established values for the pitch velocity until the blades are fully pitched out of the wind.

The pitch control systems mainly comprise mechanical and hydraulic components such as hydraulic actuators to turn the wind turbine blades in or out of the wind around their longitudinal axis.

A problem with the prior art is that the values for the pitch velocity have to be picked conservatively in order to ensure that any part of the wind turbine and especially the blades do not experience an overload situation from the controlling during the stopping process. However, if the stopping process is to slow the generator and gear means of the wind turbine may suffer damage.

A related problem is that the wind turbine and especially the blades have to be dimensioned quite robust in order to survive any force during the stopping process in which the process is prolonged by the low pitch velocity.

A further problem is the fact that the rotor may get out of control i.e. accelerate to fatale speeds due to the low pitch velocity.

An object of the invention is to establish a technique without the above-mentioned disadvantages. Especially, it is an object to establish solutions which are optimal in connection with the stopping process of wind turbine rotors and especially rotors of large modern wind turbines without causing damage to the wind turbines.

### BRIEF SUMMARY OF THE INVENTION

The invention relates to a method of controlling at least one wind turbine blade during the stopping process of the rotor in a wind turbine system e.g. during extreme situations such as loss of a utility grid or high wind, where said method optimizes the blade control velocity of said blades at least toward a position of no-acceleration force  $f_{acc}$  applied to the rotor in response to one or more feedback values of the system and/or the surroundings of the system.

Hereby is established a method without the above-mentioned disadvantages of the prior art. Especially, it is advantageous that the method allows the rotor of the wind turbine to be optimally and actively stopped in response to feedback values of the wind turbine and/or the surroundings of the wind turbine. The active control of the wind turbine blades allows the wind turbine to be stopped quickly without exposing the wind turbine to excessive forces i.e. an optimizing between time and forces in stopping the rotor.

The method is particularly advantageous in connection with the long and heavy wind turbine blades of modern wind turbines in which the possible excessive forces are quite significant.

Consequently, the method allows the wind turbine including the rotor system to be dimensioned less robust than normal as the wind turbine will not undergo considerable and potentially harmful forces during the optimal and swift stopping process.

In an aspect of the invention, said controlling includes the regulating of the pitch angle of one or more pitch or active stall wind turbine blades from the value at the initiating of the stopping process to a value of said no-acceleration position e.g. to substantially 90 degrees. To optimize the pitch control of the blades in the period from the beginning of the stopping process to the blade position of no-acceleration is established, is especially advantageous as the blade forces in this period are potentially damaging to the wind turbine if they not are brought under control quickly e.g. due to increasing rotor speed during the period. The rotor speed is contained and again under control when the no-acceleration position is reached.

In a further aspect of the invention, the regulating of the teeter angle of a rotor teeter mechanism is used in obtaining the no-acceleration of said at least one wind turbine blade. The teeter mechanism allows blade load-shedding during every rotation of the wind turbine blades in response to asymmetric wind speeds over the swept area with the use of a bearing at the rotor hub. The teeter angle is an important measuring data during the stopping process as no control of the teeter mechanism may result in unintended forces applied to the blades, impact between the blades and the tower as well as overload of the teeter mechanism.

In a further aspect of the invention, said controlling includes a closed loop configuration with said feedback values established by measuring mechanical or physical data of the system and/or the surroundings of the system such as measuring data of pitch position, blade load, teeter angle, azimuth, friction of blade bearings, wind speed, wind direction, wind share and/or wind density. Hereby, it is possible to quickly pitch the wind turbine blades to a no-acceleration position and thus reduce a rotor overspeed and without overloading the wind turbine and the blade structure. Consequently, the feedback values ensure that a fatal breakdown of the wind turbine is avoided as the critical component of the wind turbine and the surroundings are monitored and fed back to the blade control system.

The phrase "mechanical or physical data" should be understood as measuring data not concerning the generated electrical power output of the wind turbine system or other measurements relating to power generation during normal periods of power generation.

In even further aspect of the invention, the pitch velocity is controlled in relation to a non-linear curve with a higher initial slope. Hereby, it is possible to overcome any inertia and pitch the blade quickly out of the wind. The pitching may be performed closer to the physical limits of the wind turbine and especially the rotor system as the necessary data are measured, fed back and used in the continuous pitching out of the blades from the wind. Further, the velocity may be limited to a low value when the feedback values indicate that

In an aspect of the invention, the controlling of the pitch velocity comprises high initial transient from 0 to circa 15 degrees/sec in the first few seconds e.g. in the first five seconds such as between the first and third second. Hereby is an advantageous embodiment of the invention achieved and especially in connection with modern wind turbine blades of



a length beyond 30 meters e.g. blades of 39 or 44 meters and with a weight of at least 5 tons.

In another aspect of the invention, said one or more feedback values result in control values for controlling said at least one wind turbine blade within control limit values. Hereby, the wind turbine blades may be pitched with a high initial velocity and a lower succeeding velocity in response to the feedback values and thus establishing a non-linear velocity curve.

In another aspect of the invention, the pitch angles of said at least one wind turbine blade are controlled individually during every rotation of the rotor in order to obtain a substantially common force on the rotor. Hereby, the rotor may be protected against asymmetric and potentially fatal forces during every rotation in the stopping process.

In another aspect of the invention, the pitch angles of said at least one wind turbine blade are controlled in relation to a cyclic or a similar non-linear curve during every rotation of the rotor e.g. in relation to the wind speed in different sections of the swept area. Hereby, the wind turbine may be protected against damage due to fatal forces arisen from asymmetric wind forces over the swept area, unbalances in the rotor and/or the rotor control systems.

It should be understood that the pitch angle is controlled in relation to feedback values in order to deal with non-linear situations during every rotation of the rotor and thus follows the non-linear curve but is not controlled along a curve as such.

The invention further relates to a control system for controlling at least one wind turbine blade during the stopping process of the rotor in a wind turbine system e.g. during extreme situations such as loss of a utility grid or high wind, wherein the system comprises

sensor means to measure one or more values of the system and/or the surroundings of the system,  
 computing means to establish one or more feedback values of said measured values, and  
 control means to control said at least one wind turbine blade wherein said means optimizes the blade control velocity of said blades at least toward a position of no-acceleration force  $f_{acc}$  applied to the rotor in response to said one or more feedback values.

Hereby is established a control system without the above-mentioned disadvantages of the prior art. Especially, it is advantageous that the control system allows the wind turbine to be actively stopped in response to feedback values. The active control of the wind turbine blades allows the wind turbine to be stopped quickly without exposing the wind turbine to excessive forces i.e. an optimizing between time and forces during the stopping process.

The control system is particularly advantageous in connection with long and quite heavy wind turbine blades of modern wind turbines. Further, modern wind turbines and especially wind turbine blades may be designed without the standard over-dimensioning in order to survive extreme situations as the control system may stop the wind turbines before they face excessive forces.

In aspects of the invention, said control means comprises means and algorithms such as pitch actuator systems for controlling the pitch from the initiating value of the stopping process to a value of said no-acceleration position e.g. of 90 degrees of said at least one wind turbine blade such as one or more pitch or active stall wind turbine blades and/or a teeter mechanism that is used in obtaining the no-acceleration of said at least one wind turbine blade.

In another aspect of the invention, said sensor means include pitch position sensors, blade load sensors, azimuth

sensors, wind sensors, and/or teeter angle sensors for measuring mechanical or physical data of the wind turbine system and/or the surroundings of the system. Hereby is an advantageous embodiment of the invention achieved by establishing the relevant and necessary values of the wind turbine and surroundings to be used in the algorithms as feedback values during the stopping process.

In a further aspect of the invention, said system includes a closed loop configuration in order to establish said one or more feedback values. Hereby is an advantageous embodiment of the invention achieved.

In another aspect of the invention, said control means comprises means for controlling the pitch velocity in relation to a non-linear curve with a higher initial slope. Hereby is an advantageous embodiment of the invention achieved.

In an aspect of the invention, said control means comprises means for controlling the pitch velocity with a high initial transient from 0 to circa 15 degrees/sec in the first few seconds e.g. in the first five seconds such as between the first and third second. Hereby is an advantageous embodiment of the invention achieved.

In an aspect of the invention, said system controls said at least one wind turbine blade within control limit values. Hereby is an advantageous embodiment of the invention achieved.

In a further aspect of the invention, said computing means includes microprocessor and computer storage means e.g. for pitch algorithms and pre-established values of said control limit values. The use of computing means in the control means and in combination with swiftly reacting pitch actuator systems allow the wind turbine blades to be turned out of the wind without being damaged during the turning.

The invention also relates to a wind turbine with at least one pitch or active stall wind turbine blades in the rotor and a control system for controlling a pitch actuator system and the pitch angle of said at least one wind turbine in response to one or more feedback values of the wind turbine and/or the surroundings of the wind turbine during a stopping process.

In aspects of the invention, said at least one wind turbine blade is part of a wind turbine with two or three blades and said pitch actuator system includes electric motors e.g. electric stepper motors controlling the pitch angle of said at least one wind turbine blade. The use of electric motors allows the creation of precise and swiftly reacting pitch actuator systems which is advantageous in connection with the present invention.

In other aspects of the invention, said wind turbine comprises a rotor teeter mechanism and said pitch actuator system controls the pitch angles of said at least one wind turbine blade individually during every rotation of the rotor in order to obtain a substantially common force on the rotor.

In further aspect of the invention, said pitch actuator system controls the pitch angles of said at least one wind turbine blade in relation to a cyclic or non-linear curve during every rotation of the rotor e.g. in relation to the wind speed in different sections of the swept area.

#### BRIEF DESCRIPTION OF THE FIGURES

The invention will be described in the following with reference to the figures in which

FIG. 1 illustrates a large modern wind turbine including three wind turbine blades in the wind turbine rotor,

FIG. 2 illustrates an example of the wind force distribution that the wind turbine rotor faces during rotation,

FIG. 3 illustrates schematically the functionality of a pitch system in a pitch controlled wind turbine,



## 5

FIGS. 4 and 5 illustrate the functionality and pitch velocity of a well-known control system for controlling the wind turbine blades,

FIG. 6 illustrates the pitch angle control strategy of a control system for controlling the wind turbine blades,

FIGS. 7 and 8 illustrate the functionality and pitch velocity of a control system for controlling the wind turbine blades according to the invention,

FIG. 9 illustrates a pitch angle control strategy of a control system as illustrated in FIG. 7,

FIG. 10 illustrates schematically a preferred embodiment of a control system for controlling the wind turbine blades during a stopping process.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a modern wind turbine 1 with a tower 2 and a wind turbine nacelle 3 positioned on top of the tower. The blades 5 of the wind turbine rotor are connected to the nacelle through the low speed shaft which extends out of the nacelle front.

As illustrated in the figure, wind over a certain level will activate the rotor and allow it to rotate in a perpendicular direction to the wind. The rotation movement is converted to electric power which usually is supplied to the transmission grid as will be known by skilled persons within the area.

FIG. 2 illustrates the distribution of the wind forces which the large rotor 6 faces e.g. strong wind forces at the top of the rotor (e.g. 10 meter per second) and decreasing wind forces (e.g. from 8 to 2 meter per second) toward the bottom of the rotor. The rotor faced distribution of wind forces may result in a very strong moment on the wind turbine in which the wind forces literally try to break off the nacelle from the tower or the foundation. The wind turbine blades are controlled individually in order to level the distribution of wind forces i.e. pitched less into the wind at the top than at the bottom of the rotating movement performed by the rotor including the blades. This technique is called cyclic pitch of the wind turbine blades i.e. a cyclic change of the pitch angle during a full rotation of a blade.

The asymmetric wind forces may arise or be increased by wind shear or wind wake from other wind turbines in a wind park or from meteorological or geographical conditions.

FIG. 3 illustrates schematically the functionality of a pitch system in a pitch controlled wind turbine. The turbine is illustrated with just one wind turbine blade 5. The blade is illustrated in two positions in relation to the wind direction; a work position "a" and a no-acceleration or no-energy position "b", respectively, and (not illustrated) a parking position. The blade is in the position b pitched or turned out of the wind around its longitudinal axis to such extent that an acceleration force  $f_{acc}$  is zero i.e. a no-acceleration position for the wind turbine rotor. The position a illustrates the wind turbine blade 5 in any normal working position in which the blade has been pitched or turned into the wind whereby the wind establishes lifting forces on the blade making the wind turbine rotor and the shaft rotate. The angle  $\Phi$  is the angle from the positions a through b to the parking position and thus the angle from a given working position through the no-acceleration position to the parking position i.e. the angle which the wind turbine blade must be pitched during a stopping process such as an emergency stop of a wind turbine in order to protect it by removing forces from the blade (and thus the rest of the wind turbine).

The wind affects the blade profile of the wind turbine blade with an orthogonally directed force  $F_{lift}$  and a parallel directed force  $F_{drag}$  on the blade profile. There is a force surplus and

## 6

the wind turbine blade will accelerate if the sum of vector components points forward. And decelerate if the sum of vector components points backward.

FIGS. 4 and 5 illustrate the functionality of a previous control system for controlling the wind turbine blades.

FIG. 4 illustrates schematically how a controller 7 controls the flex model 8 representing a pitch controlled wind turbine blade 5 of the rotor 6 in a wind turbine 1 during the stopping process. The continuously variable pitch may operate with an angle  $\Phi$  between 0 and 90 degrees in which the parking position represents the wind turbine blade being substantially out of the wind.

From the normal operating position to the parking position is the angle  $\Phi$  which the wind turbine blade must be turned in order to stop the rotor from rotating. The angular velocity defines the pitch time from an operating position to a parking position of the wind turbine blade.

The blade pitching of the wind turbine system is normally carried out by a hydraulic system with tank and pumps placed in the nacelle, whereas servo valve and cylinders are placed in the hub. The cylinders are provided with pressurized oil through the hollow low-speed shaft and a rotating oil inlet. The control of the hydraulic system is usually established by a system of electric relays.

FIG. 5 illustrates an example of a curve relation of applied force to achieve an angular pitch velocity over time in connection with the controller of FIG. 4 i.e. a curve over the acceleration of the system.

The curve comprises a first and second level of applied force to the wind turbine blade in which the first level is higher than the second in order to initiate the pitching of the blade and resulting in a substantially linear or constant angular pitch velocity from an operating position to a no-energy or parking position. The levels are chosen rather conservative with a significant margin to any level that may cause damage to the wind turbine blade or the other wind turbine components.

The o/sec on the figure should be understood as °/sec i.e. degrees per second.

FIG. 6 illustrates the pitch angle control strategy of a control system for controlling the wind turbine blades in a wind turbine rotor as illustrated in FIG. 4. Each of the three curves illustrates the behavior of a wind turbine blade during a normal and a stopping period of the rotor in which the stopping process starts at circa 360 degrees i.e. one rotor rotation after curve start and circa one and a half rotor rotation before a pitch angle of 90 degrees is reached.

The strategy comprises pitching in relation to the wind speed over the swept area whereby the pitch angle is changed cyclic in every rotation of the rotor i.e. the blades are swept in and out of the wind during a rotation. When the stopping process of the rotor is started the blades are pitched as illustrated in FIGS. 4 and 5 i.e. with a linear pitch velocity over time forcing the blades to follow the illustrated curves in FIG. 6.

FIGS. 7 and 8 illustrate the functionality and pitch velocity of a control system for controlling the wind turbine blades according to the invention.

FIG. 7 illustrates schematically how a controller 7 controls the flex model 8 representing a pitch controlled wind turbine blade 5 of the rotor 6 in a wind turbine 1 during the stopping process. The controller 7 optimizes the pitch velocity of the wind turbine blades during the stopping process in response to one or more feedback values from feedback means 9. The feedback values are established by sensors in the wind turbine system 1 and/or at the surroundings of the wind turbine system 1. The sensors of the surroundings may detect or monitor



the wind speed, wind direction, wind share and/or wind density as well as other relevant values of the surroundings.

FIG. 8 illustrates an example of a curve relation of applied force to achieve an angular pitch velocity over time of the present invention i.e. a curve over the acceleration of the system.

The curve includes an initial high transient acceleration from 0 to circa 15 degrees/sec in the first few seconds e.g. in the first five seconds such as between the first and third second. The curve forms a steady-state after the initial transitory condition in which a no-acceleration position is reached. Hereby, is assured that the angular pitch velocity has a high initial value and a lower succeeding value and thus forms a non-linear velocity curve.

The wind turbine may in an emergency situation (e.g. loss of utility load on the electric generator in which a fatal rotor runaway is imminent or high wind situations) be stopped by quickly pitching the wind turbine blades to a "dynamic stability position" in which the force accelerating the blades  $F_{acc}$  is zero (the no-acceleration position). The blades may hereafter be brought to a full stop in a slower pace. The necessary pitch angle for obtaining dynamic stability depends on different wind speeds but is typically circa 10-15°. The wind turbine blades should be pitch individually in order to overcome any unbalance in the rotor e.g. one blade with a slower reacting pitch system than the other blade or blades. The correct approach in this situation may for example be to slow down the other blade pitch systems in order to avoid any structural damage to the wind turbine due to unbalance in the rotor. The stopping process of the wind turbine may hereafter continue as the necessary rotor balance is achieved.

The o/sec on the figure should be understood as °/sec i.e. degrees per second.

FIG. 9 illustrates a preferred pitch angle control strategy of a control system as illustrated in FIG. 7.

Each of the three curves illustrates the behavior of a wind turbine blade during a normal and a stopping period of the rotor in which the stopping process starts at circa 360 degrees i.e. one rotor rotation after curve start and circa one and a half rotor rotation before a pitch angle of 90 degrees is reached.

The strategy comprises pitching in relation to the wind speed over the swept area whereby the pitch angle is changed cyclic in every rotation of the rotor i.e. the blades are swept in and out of the wind during a rotation. When the stopping process of the rotor is started the blades are pitched as illustrated in FIGS. 7 and 8 with a non-linear pitch velocity over time and feedback values allowing the pitch angle of the blades to follow the optimal curves as illustrated in FIG. 9 e.g. with a cyclic pitch in the stopping process.

FIG. 10 illustrates schematically a preferred embodiment of a control system for controlling the wind turbine blades during a stopping process.

Data of the wind turbine 1 and/or the surroundings of the wind turbine are measured with sensor means 11 such as pitch position sensors, blade load sensors, tower load sensors, foundation sensors, azimuth sensors and/or teeter angle sensors. The measured sensor data are supplied to computing means 11 in order to convert the data to a feedback signal. The feedback signal is used in the controller 12 for controlling the pitch by establishing control values MF for controlling said at least one wind turbine blade 5 within control value limits +MF, -MF. The feedback signal and control values W are considered to be signals which control the blade pitch in such a way that no part of the wind turbine is affected by overloads during a stopping process e.g. in extreme situations such as loss of utility grid or high wind situations.

The control values may preferably be force and/or torque values.

The computing means 11 preferably includes a microprocessor and computer storage means for pre-established limit values of said control values to be compared with the present control values MF. By continuously comparing the present control values with the pre-established values in a closed feedback loop it is possible to optimize the control values to (substantially) to control the rotor at the design limits of the wind turbine and especially the design limits of the wind turbine blades.

The invention has been exemplified above with reference to specific examples of a wind turbine with a control system for controlling the wind turbine blades during the stopping process. However, it should be understood that the invention is not limited to the particular examples described above but may be designed and altered in a multitude of varieties within the scope of the invention as specified in the claims e.g. in using other measuring data as a supplement or instead of the abovementioned such as temperature measurements in the relevant components of the wind turbines.

The invention claimed is:

1. Method of controlling at least one wind turbine blade during a stopping process of a rotor in a wind turbine system, said method comprising:

optimizing blade control velocity of said blades at least toward a position of no-acceleration force applied to the rotor in response to one or more feedback values of the system and/or the surroundings of the system, and controlling pitch angles of said at least one wind turbine blade in relation to a cyclic or a similar non-linear curve during every rotation of the rotor.

2. Method according to claim 1, where said controlling includes regulating of the pitch angle of one or more pitch or active stall wind turbine blades from a value at an initiating of the stopping process to a value of said no-acceleration position.

3. Method according to claim 1, where regulating of a teeter angle of a rotor teeter mechanism is used in obtaining the no-acceleration of said at least one wind turbine blade.

4. Method according to claim 1, where the pitch angles of said at least one wind turbine blade are controlled individually during every rotation of the rotor in order to obtain a substantially common force on the rotor.

5. Method according to claim 1, where said controlling includes a closed loop configuration with said feedback values established by measuring mechanical or physical data of the wind turbine system and/or the surroundings of the system.

6. Method according to claim 5, where said one or more feedback values result in control values for controlling said at least one wind turbine blade within control limit values.

7. Method according to claim 1, where a pitch velocity is controlled in relation to a non-linear curve with a higher initial slope.

8. Method according to claim 7, where the controlling of the pitch velocity comprises a high initial transient from 0 to circa 15 degrees/sec in the first few seconds.

9. Method according to claim 1, where the pitch angles of said at least one wind turbine blade are controlled in relation to a cyclic or a similar non-linear curve during every rotation of the rotor in relation to wind speed in different sections of the swept area.

10. Control system for controlling at least one wind turbine blade during a stopping process of a rotor in a wind turbine system, wherein the control system comprises:



9

sensor for measuring one or more values of the system and/or the surroundings of the system, computing means for establishing one or more feedback values of said measured values, and

controller for controlling said at least one wind turbine blade wherein said controller optimizes a blade control velocity of said blades at least toward a position of no-acceleration force applied to the rotor in response to said one or more feedback values, and wherein said controller controls pitch angles of said at least one wind turbine blade in relation to a cyclic or a similar non-linear curve during every rotation of the rotor.

11. Control system according to claim 10, wherein said controller comprises means and algorithms for controlling the pitch from the initiating value of the stopping process to a value of said no-acceleration position.

12. Control system according to claim 10, wherein said controller comprises a teeter mechanism that is used in obtaining the no-acceleration of said at least one wind turbine blade.

13. Control system according to claim 10, wherein said sensor include pitch position sensors, blade load sensors, azimuth sensors, wind sensors, and/or teeter angle sensors for measuring mechanical or physical data of the wind turbine system and/or the surroundings of the system.

14. Control system according to claim 10, wherein said system includes a closed loop configuration in order to establish said one or more feedback values.

15. Control system according to claim 10, wherein said controller comprises means for controlling the pitch velocity in relation to a non-linear curve with a higher initial slope.

16. Control system according to claim 10, wherein said controller comprises means for controlling the pitch velocity with a high initial transient from 0 to circa 15 degrees/sec in the first few seconds.

17. Control system according to claim 10, wherein said system controls said at least one wind turbine blade within control limit values.

10

18. Control system according to claim 17, wherein said computing means includes microprocessor and computer storage means for pitch algorithms and pre-established values of said control limit values.

19. Control system according to claim 10, wherein pitch algorithms control the pitch angles of said at least one wind turbine blade individually during every rotation of the rotor in order to obtain a substantially common force on the rotor.

20. Control system according to claim 19, wherein pitch algorithms control the pitch angles of said at least one wind turbine blade in relation to a cyclic or a similar non-linear curve during every rotation of the rotor.

21. Wind turbine with at least one pitch or active stall wind turbine blade in a rotor and a control system according to claim 10 for controlling a pitch actuator system and pitch angle of said at least one wind turbine blade in response to one or more feedback values of the wind turbine and/or the surroundings of the wind turbine during a stopping process.

22. Wind turbine according to claim 21, wherein said at least one wind turbine blade is part of a wind turbine with two or three blades.

23. Wind turbine according to claim 21 wherein said pitch actuator system includes electric motors controlling the pitch angle of said at least one wind turbine blade.

24. Wind turbine according to claim 21, wherein said wind turbine comprises a rotor teeter mechanism.

25. Wind turbine according to claim 21, wherein said pitch actuator system controls the pitch angles of said at least one wind turbine blade individually during every rotation of the rotor in order to obtain a substantially common force on the rotor.

26. Wind turbine according to claim 21, wherein said pitch actuator system controls the pitch angles of said at least one wind turbine blade in relation to a cyclic or non-linear curve during every rotation of the rotor.

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